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MILESIINE FLOWER FLIES (DIPTERA: SYRPHIDAE) IN A CENTRAL APPALACHIAN BROADLEAF FOREST: ABUNDANCES, FLIGHT PERIODS, AND DIFLUBENZURON

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Abstract.—We used 20 Malaise traps to collect adult milesiine syrphids in four watersheds in a central Appalachian broadleaf forest during early April through late September in 1991 through 1993. The traps captured 31 species in 12 genera. As a group, these flies flew throughout our annual sampling periods, their sample sizes varied with species and year, and their abundances peaked in late May or mid-June, depending on the year. For all species whose sample size was ≥10 individuals, male-female sex ratios varied from 0.1 through 3.0. We performed a split-plot analysis of flies captured from mid-May through early August, a period in each of the 3 years when traps captured at least one fly during a sampling period. This analysis did not find an effect of trap site or diflubenzuron on fly population sizes based on Malaise sampling, because these effects did not exist or our sample size was too small to detect them.

Key Words: Appalachian forest, diflubenzuron, Malaise traps, phenology, Syrphidae

The broad aims of our study are to learn more about the biology of syrphid flies in the tribe Milesiini and determine whether aerially-applied diflubenzuron affects population sizes of these beneficial insects in a temporate broadleaf forest. Diflubenzuron (Dimilin®, Uniroyal) is an insect growth regulator used to control forest and other pest arthropods. We report which milesiine species are present in this forest and their flight periods, seasonal abundances, and sex ratios, based on sampling with Malaise traps. Further, we used a split-plot analysis to test the hypotheses that diflubenzuron and trap site affect the number of individuals captured.

Milesiine syrphids are beneficial insects in forests and other habitats, where they may be Batesian mimics of some stinging hymenopterans, honeydew consumers, food for other organisms, nectarivores, pollenivores, pollinators, and scavengers (Gilbert 1981, 1986; Maier 1982; Vockeroth and Thompson 1987; Waldbauer 1988; Owen 1991). We studied this syrphid taxon because its members have diverse habits and are taxonomically well known and easily identified. Syrphids and bees are the major pollinators in many habitats.

Federal and state agencies have treated thousands of hectares of forests with diflubenzuron to control gypsy moths, *Lymantria dispar* (L.), in the eastern United States (USDA Forest Service 1994). This pesticide also reduces the numbers of nontarget, beneficial forest insects including honey bees (Egger 1977), macrolepidopterans and nonlepidopteran mandibulate herbivores (Martinat et al. 1988); macrolepidopterans (Sample et al. 1993; Butler et al. 1997), stoneflies (Griffith et al. 1996), and yellowjackets (Barrows et al. 1994). However, there are no published reports regarding the possible effects of aerially-applied diflubenzuron on forest syrphids.

Materials and Methods

We studied syrphids in the 1,902-ha Fernow Experimental Forest in Tucker County, West Virginia, over a 3-year period (1991–1993). Detailed accounts of our materials and methods are published in Barrows et al. (1994) and Barrows (1995).

The Fernow Experimental Forest is from 533 to 1,112 m in elevation and has slopes up to 60%, a mean of 145 frost-free days, a mean annual precipitation of 147 cm, and mean temperature of 9°C (Anonymous 1987). *Acer rubrum* L., *Betula lenta* L., *Fagus grandifolia* Ehrhart, *Liriodendron tulipifera* L., *Prunus serotina* Ehrhart, and *Quercus* spp. are common trees in this forest.

We used watersheds 1, 4, 7, and 13 as study areas. Watersheds 1, 7, and 13 are conterminous, and watershed 4 is about 200 m from watershed 7 (Adams et al. 1994, map). Watersheds 1 and 13, the diflubenzuron-treated plots (test plots) totaled 42 ha, and watersheds 4 and 7, the control plots totaled 63 ha. On 16 May 1992, the USDA Forest Service aerially applied diflubenzuron (Dimilin[R] 4L) with a helicopter at 35.1 g (AI) ha^{-1} to watersheds 1 and 13.

During April through September, all 3 study years were drier than a 41-year average of 76 cm for the Fernow Experimental Forest, 1991 and 1993 were warmer than average (15.9°C), and 1992 was cooler than average. During these months, mean temperature was 17.6, 14.9, and 17.1°C, and the mean precipitation was 56.9, 59.9 and 64.3 cm, in 1991, 1992, and 1993, respectively.

We captured flies from 29 April through 27 September 1991–1993 using five Townes-style Malaise traps (Townes 1972; manufactured by Golden Owl Publishers, Lexington Park, MD) placed 20–35 m apart on the ground in a transect in each of the watersheds as illustrated in Barrows et al. (1994). Each transect ran across a valley and approximately perpendicularly to a second-order stream. From the vantage point of looking upstream, two traps were on the left side and two were on the right side of a central trap. Valley left sides had northerly exposures, and right sides had southerly exposures. The central trap of each transect was from 0 to 6 m from the edge of a stream. We placed all traps on the forest floor, not on logging roads or in other artificial openings.

A trap was made of 1-mm-mesh, nylon gauze, a supporting frame, and a collecting head. A 0.95-liter jar, which was part of the head and contained 95% ethanol, collected the flies as well as thousands of species of other arthropods. Each trap was 1.2 m wide, 1.7 m long, 1.0 m high at its back, and 2.0 m high at its front (head end). Trap roofs were made of white gauze and baffles and sides were made of black gauze. We emptied our 20 traps every 10 d on the same Julian day in April through September in 3 yr, totaling 895 samples.

Falling tree limbs, mice, bears, and possibly other animals occasionally damaged our traps; we repaired, or replaced, them as soon as we found damage. Five samples were incomplete because of trap damage and could not be used in our statistical analyses. We identified syrphids to genus using keys in Vockeroth and Thompson (1987) and to species with the reference collection at the National Museum of Natural History, Smithsonian Institution, and deposited a voucher collection of these flies in that Museum. For species with large enough sample sizes for analysis, we used χ^2 goodness of fit tests to determine whether they had sex ratios that significantly differed from male-female sex ratios of 1:1, 1:2, and 2:1. To look for a possible difference in the number of syrphid individuals among years, we used analysis of variance. Finally, we used a split-plot analysis to look for possible diflubenzuron and trap-site effects on the number of captured flies (PROC

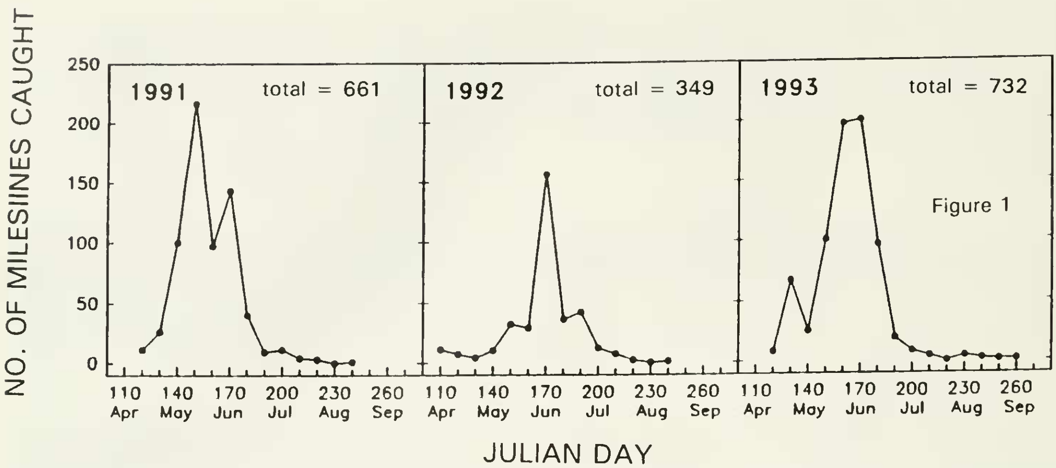

Fig. 1. Numbers of milesiines captured in each 10-day sample in the four watersheds, Fernow Experimental Forest, 1991–1993.

MIXED, SAS Institute 1992). The treatments were pesticide (with the two levels application and nonapplication) and trap site (five levels or locations). We calculated the grand mean of the trap means of flies for eight sampling periods (mid-May through early August) per watershed per year. This was a period when most milesiines flew and there was at least 1 fly per sampling period in each of the 3 sampling years. In 1991, the preapplication year, milesiine populations were higher in the application watersheds than in the nonapplication watersheds, possibly because the former were better syrphid habitats. To adjust for this difference, we analyzed the differences between the 1991 and 1992 and between the 1991 and 1993 grand means, testing the null hypothesis that the difference between the application-watershed means of fly number equals the difference between the nonapplication-watershed means of fly number. To look for a possible trap-site effect, we tested the null hypothesis that the mean numbers of flies from the five trap sites are equal.

Results and Discussion

Species, sex ratios, flight periods, and abundances.—Traps collected a total of 1,742 milesiines belonging to 31 species in 12 genera (Fig. 1, Table 1–2). The Fernow Experimental Forest is within the previously known ranges of all of these species; however, this is the first published species list of Milesiini from a central Appalachian broadleaf forest.

By the ends of 1991, 1992, and 1993, our traps obtained 84%, 94%, and 100% of the 31 milesiine species, respectively. Some species were rare in samples, and not all species were in samples every year. The six most common species comprised 76% of the 1,742 collected specimens.

We were unable to run our traps for more than 3 years, but Owen's (1991) study suggests that our traps may have obtained the majority of the milesiine species in our study site during our three-season study period. She caught 43,749 individuals in 91 species and 41 genera, by using one Townes-style Malaise trap (Townes 1972) in her British garden for 15 successive years. The trap obtained the vast majority of its total number of syrphid species by the end of its fifth year of operation, rarely caught some species, caught markedly varying numbers of some species from year to year, and obtained a previously uncaught species during most years from the 5th through 15th years of operation. Bańkowska (1980) found 25 species in seven mile-

Table 1. Abundances of milesiine syrphids and percentages of males collected in Malaise traps from late April through late September, in all four watersheds in the Fernow Experimental Forest, West Virginia, 1991–1993.

Species	Number Captured	% Males[a]
Blera analis (Macquart)	30	47[b]
B. badia (Walker)	263	65[c]
B. nigra Williston	1	100
B. pictipes (Bigot)	15	53[b]
B. umbratilis (Williston)	1	100
Brachypalpus oarus Walker	102	47[b]
Chalcosyrphus inarmatus (Hunter)	20	55[b]
C. libo (Walker)	17	29[d]
C. nemorum (F.)	6	17
C. plesius Curran	2	100
C. vecors Osten Sachen	3	33
Criorhina nigriventris Walton	9	22
C. verbosa Walker	36	17
Lejota aerea (Loew)	9	56
Pterallastes thoracicus Loew	123	37[d]
Somula decora Macquart	25	24
Specomyia vittata Wiedemann	30	23
Spilomyia alcimus (Walker)	4	100
S. fusca Loew	9	22
Temnostoma alternans Loew	111	57[b]
T. balyras Walker	573	52[b]
T. barberi Curran	21	10
T. trifasciatum Robertson	11	27
T. venustum Williston	8	25
T. vespiforme (L.)	167	69[c]
Teuchocnemis lituratus (Loew)	66	50[b]
Xylota 78-1 Thompson	4	25
X. 78-3 Thompson	17	29[d]
X. bicolor Loew	22	36[d]
X. nebulosa Johnson	1	100
X. quadrimaculata Loew	36	17
Total	1,742	

[a] The proportion of males for all species combined is 47%.

[b] This sex ratio is not different than 1.0 or 50% males (df = 1, $P < 0.05$, χ^2 goodness of fit test).

[c] This sex ratio is not different than 2.0 or 66% males (df = 1, $P < 0.05$, χ^2 goodness of fit test).

[d] This sex ratio is not different than 0.5 or 33% males (df = 1, $P < 0.05$, χ^2 goodness of fit test).

siine genera in Polish broadleaf forests, compared to the 31 species in 12 genera reported in our study (Table 1).

In our study, male-female milesiine sex ratios varied from 0.1 through 3.0. Four species had male-female sex ratios that were not different from 1:2; seven species, 1:1; and two species 2:1 (Table 1). In all species in all 3 years, 47% of the syrphids were males which is not different than a 1:1 sex ratio (50% males) (df = 1, χ^2 = 2.431, P = 0.119). Deviations from a 1:1 sex ratio in certain species may be due to factors including having an adult sex ratio that is actually different from 1:1 and one sex's being more likely to be trapped than the other.

Milesiines flew throughout most of our monitoring period; however, the traps collected the vast majority (95%) of them from early May through late July (Fig. 1, Table 2). Traps acquired individual milesiine species for an mean of 59.4 ± 5.6 SEM days (range 10–130 days, 31 species), obtaining all species except for *Chalcosyrphus nemorum* (F.) and *Pterallastes thoracicus* Loew, for 100, or fewer, days. This mean and ranges are approximations because our sampling intervals were 10 days.

Of the species with sample sizes of 10 or more individuals, three species peaked in abundance in early May; three in mid-May; one in late May; one in early June; eight in mid-June; and one in late June (Table 2). The main annual peaks were in late May 1991 and mid-June in 1992 and 1993 (Fig. 1). The troughs between the two large peaks in 1991 and 1993 coincide with rainy periods. Visnyovszky (1988) also found rain-related drops in Malaise-trap sample sizes in these flies in Hungarian apple orchards.

Among flies in the traps, *Temnostoma balyras* Walker was the most common, followed by *Blera badia* (Walker), *T. vespiforme* L., *Pterallastes thoracicus,* and *T. alternans* Loew (Table 1). The only published study of North American Milesiine flight periods is based on the faunas of Piatt and Mason Counties in central Illinois, both approximately 40° north, and Emmet County in northern lower Michigan, approximately 45° north (Waldbauer 1988). This study involved high-fidelity mimics of stinging hymenopterans which were sampled by hand netting. Our study site (approximately 39°

Table 2. Abundances of milesiine syrphids and percentages of males collected in Malaise traps from late April through late September, in all four watersheds, Fernow Experimental Forest, West Virginia, 1991–1993[a]

	Month and Sampling Period[b]															
	April	May			June			July			August			September		
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Blera analis	0	0	1	3	4	**20**	1	0	1	0	0	0	0	0	0	0
B. badia	2	2	5	35	78	**93**	32	15	1	2	0	0	0	0	0	0
B. nigra	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B. pictipes	0	0	0	**7**	1	4	1	0	0	0	0	0	0	0	0	0
B. umbratilis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Brachypalpus oarus	12	**59**	17	11	0	0	1	0	0	0	0	0	0	0	0	0
Chalcosyrphus inarmatus	0	1	**8**	5	4	1	1	0	0	0	0	0	0	0	0	0
C. libo	1	**4**	**4**	**4**	0	2	1	1	0	0	0	0	0	0	0	0
C. nemorum	0	0	1	1	0	1	1	1	0	0	0	0	1	0	0	0
C. plesius	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
C. vecors	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
Criorhina nigriventris	2	1	4	2	0	0	0	0	0	0	0	0	0	0	0	0
C. verbosa	6	**16**	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Lejota aerea	0	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterallastes thoracicus[c]	0	0	1	9	15	**41**	18	13	14	3	4	2	1	1	1	0
Somula decora[c]	0	0	0	6	**9**	5	4	1	0	0	0	0	0	0	0	0
Specomyia vittata[c]	6	0	7	**16**	2	4	0	1	0	0	0	0	0	0	0	0
Spilomyia alcimus[c]	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0
S. fusca[c]	0	0	0	0	0	0	0	2	0	4	0	1	2	0	0	0
Temnostoma alternans[c]	0	0	6	29	13	**60**	16	3	3	0	1	0	0	0	0	0
Temnostoma balyras[c]	2	17	28	136	136	**154**	43	19	2	1	0	0	0	0	0	0
T. barberi[c]	0	0	1	5	**6**	**6**	2	0	0	0	0	0	0	0	0	0
T. trifasciatum[c]	0	0	0	0	**5**	4	1	1	0	0	0	0	0	0	0	0
T. venustum[c]	0	0	1	1	1	1	1	1	2	0	0	0	0	0	0	0
T. vespiforme[c]	0	0	9	36	19	**82**	14	7	0	0	0	0	0	0	0	0
Teuchocnemis lituratus	0	3	**25**	21	6	6	3	0	2	0	0	0	0	0	0	0
Xylota bicolor	0	0	0	0	3	6	**9**	1	2	0	0	1	0	0	0	0
X. nebulosa	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
X. quadrimaculata	0	0	2	4	8	**9**	6	4	1	1	1	0	0	0	0	0
X. n. sp. 1	0	0	0	0	0	1	2	0	1	0	0	0	0	0	0	0
X. n. sp. 2	0	**4**	3	**4**	2	3	0	0	1	0	0	0	0	0	0	0
Totals	31	113	129	340	312	**507**	169	70	30	14	6	4	4	1	1	0

[a] Sample peaks in species with ≥10 specimens are in bold face.
[b] 1 = April: Julian days 110–120; May: 2 = 120–130; 3 = 130–140; 4 = 140–150; June: 5 = 150–160; 6 = 160–170; 7 = 170–180; July: 8 = 180–190; 9 = 190–200; 10 = 200–210; August: 11 = 210–220; 12 = 220–230; 13 = 230–240; September: 14 = 240–250; 15 = 250–260; 16 = 260–270.
[c] High-fidelity mimics of stinging hymenopterans (Waldbauer 1988).

north) shares three milesiine species with each of the Illinois sites and seven species with the Michigan site. Approximate milesiine flight periods in West Virginia are similar to those in the Illinois sites. Their flight periods in West Virginia were earlier and longer than those in Michigan.

The mean numbers of milesiines captured in nonapplication watersheds per trap per sampling period was 2.7 ± 0.7, 1.7 ± 0.7, and 3.4 ± 0.7 SEM in 1991, 1992, and 1993, respectively, showing a difference in number of individuals among years (ANOVA, df = 10, $F = 5.94$; $P = 0.0199$).

Malaise traps are an excellent means for monitoring population sizes of insect taxa that are readily captured by these traps. However, they probably never collect target taxa in the exact proportions that they occur in their communities (Barrows 1986; Dar-

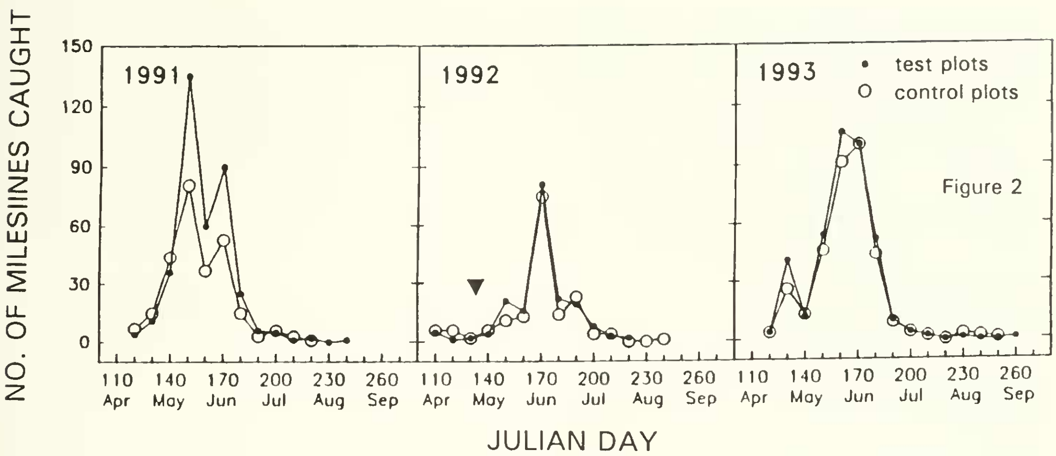

Fig. 2. Numbers of milesiines captured in each 10-day sampling period in application and nonapplication watersheds, Fernow Experimental Forest. The arrow indicates the time of pesticide spraying on application plots.

ling and Packer 1988; Archer 1990). Visual counts of some syrphid species suggested that a Malaise trap did not collect them in the proportions that they occurred near the trap (Owen 1991).

Trap-site and diflubenzuron.—Our split-plot analysis detected no diflubenzuron, or trap-site, effect on milesiines ($P > 0.05$, for both factors) (Fig. 2, Table 3). However, this finding does not indicate that aerially-

Table 3. Split-plot analysis of possible diflubenzuron and trap-site effects on numbers of milesiine syrphids.

Treatments	Year	Mean ± 1 SEM[a]	P[b]
No pesticide (1 and 13)	1991	4.2 ± 0.90	not applicable
No pesticide (4 and 7)		2.7 ± 0.53	
Pesticide (1 and 13)	1991 minus 1992	2.2 ± 0.64a	0.2016
No pesticide (4 and 7)		0.9 ± 0.64a	
Pesticide (1 and 13)	1991 minus 1993	−0.3 ± 0.98a	0.4642
No pesticide (4 and 7)		0.7 ± 0.98a	
Trap 1	1991	2.6 ± 0.81a	0.2297
Trap 2		1.9 ± 0.81a	
Trap 3		2.0 ± 0.81a	
Trap 4		3.1 ± 0.81a	
Trap 5		3.4 ± 0.81a	
Trap 1	1992	1.8 ± 0.55a	0.3438
Trap 2		1.3 ± 0.55a	
Trap 3		1.6 ± 0.55a	
Trap 4		1.9 ± 0.55a	
Trap 5		2.9 ± 0.55a	
Trap 1	1993	4.6 ± 1.11a	0.8302
Trap 2		3.5 ± 1.11a	
Trap 3		3.0 ± 1.11a	
Trap 4		3.2 ± 1.11a	
Trap 5		3.9 ± 1.11a	

[a] This mean is the average number of syphids per 10-day sample per year per watershed. Within a year, means followed by the same letter are not different from each other ($P \leq 0.05$, least-squares-means test). These means are based on two control, or test, plots per year, or four traps per subplot per year.

[b] The null hypothesis is that the means within groups (pesticide treatment or trap-site treatment) are equal.

applied diflubenzuron would never decrease milesiine populations in forests. We might not have detected a possible diflubenzuron effect because our sample size was small, milesiines might have entered our test watersheds from untreated ones and masked a pesticide effect, or both. No apparent effect of trap site on milesiine sample size suggests that these flies were relatively evenly distributed in our sample area.

In conclusion, we report that 31 milesiine species occurred in a central Appalachian broadleaf forest and they were of markedly different abundances and sex ratios in Malaise-trap samples. Although, our study found no evidence that diflubenzuron affected milesiine population sizes, a more comprehensive study might find such an effect. This pesticide remains on treated leaves for many months on plants and in leaf litter (Wimmer 1995), and larval milesiines are scavengers which could be poisoned by them. If forest managers continue to use diflubenzuron to control gypsy moths and other forest pests, more studies of this pesticide and syrphids are warranted.

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